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ABSTRACT

In recent research, two qualitatively different classes of mental operations have been identified. The performance of one type of cognitive task requires attention, in the sense of mental effort, for its execution, while the second type can be performed automatically, independent of attentional control. Further research has shown that automatic cognitive operations can be performed without attentional control when three criteria are met: an independence of performance and processing load; the presence of benefit without cost in the use of advance information; and the lack of an instructions effect. Research gerontologists have proposed that deficits in effortful processing occur during normal human aging, whereas the efficiency of automatic processes remains relatively constant over age. However, relatively little evidence has been found to support this theory. In tasks that are not affected by instructions, such as judgments regarding frequency of occurrence, age differences are reported in some experiments but not in others. In experiments that have examined age differences in visual search and the use of advance information, the criteria for identifying performance as automatic have not been met. As a result, it is too early to add developmental invariance as an additional criterion for automaticity. (BL)

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AUTOMATICITY AND ATTENTIONAL PROCESSES IN AGING[1]

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As Daniel Kahneman pointed out in his 1973 book, attention possesses an intensive aspect, which is reflected in the amount of mental effort that is expended during performance of a particular cognitive task. During the last several years a distinction has frequently been drawn between two qualitatively different classes of mental operations: those that require attention--in the sense of effort--for their execution, and those that can be performed automatically, independently of attentional control. This distinction, between processes that are attention-demanding (or effortful) and those that are automatic, is based on several criteria, which vary somewhat according to the type of task that is being performed. It has recently been proposed that the distinction between automatic and effortful processes is relevant to the interpretation of the deficits in cognitive functioning that frequently accompany normal human aging. Today I would like to discuss three criteria for automaticity in perceptual and memory tasks, and to assess the contribution of the automatic/effortful distinction to theories of age-related changes in congition.

In choice reaction-time tasks that require subjects to perform a search, either through a set of items held in memory or through those presented in a visual display, an important criterion for automaticity is an independence between performance and the number of items to be searched. In other words, automatic processing is inferred from an independence between search performance and processing load. In search tasks that require effortful processing, in contrast, reaction time and error rate both increase as the number of items to be searched is increased. The prototypical example of this type of distinction between effortful and automatic processes is the research program of Shiffrin and Schneider (1977), in which a search task is performed under two conditions. In a consistent-mapping condition, the

particular stimuli that are assigned to the yes and no responses remain constant over the trial series. In a varied-mapping condition, on the other hand, individual stimuli are assigned to both yes and no responses over the course of the trial sequence. Shiffrin and Schneider demonstrated that, after extensive practice, subjects' search performance was independent of processing load in the consistent mapping condition, but was dependent on processing load in the varied-mapping condition. This difference is illustrated in the first slide. /slide 1 about here/ Thus, in this type of visual-search task, the consistent assignment of stimuli to responses can eventually lead to substantial reductions in the amount of effort required by the task.

Another criterion for automaticity involves the effects of advance information in a choice reaction-time task. This criterion requires that the presentation of advance information leads to benefits in performance, as measured by decreases in choice reaction-time, and does not lead to "cost"--a decrement in performance--as measured by an increase in reaction time. This criterion for automaticity has been frequently investigated in the lexical decision paradigm, a task that requires subjects to decide, on each trial, whether a visually presented "target" letter string is a word or a nonword. The performance of young adults in the lexical decision task, especially on the word-target trials, is significantly influenced by the nature of a "prime" letter string that is presented just prior to the target, even though no response to the prime is required. Specifically, responses to the word targets are faster and more accurate when these targets are preceded by a semantically related word-prime than when they are preceded by a "neutral" prime, such as a string of X's, which does not provide any advance information. /slide 2 about here/ In the present example, the decision

that "chair" is a word would be made more rapidly than the decisions regarding either "fence" or "water," since information in long-term memory that is relevant to the identification of "chair" has been activated by the prime "table." Assuming that subjects cannot predict whether the prime will be related, unrelated, or neutral on a particular trial, the definition of the facilitation obtained on the related-prime trials as automatic or effortful is determined by the results that occur on those trials on which the prime is not semantically related to the target. /slide 3 about here/ Under some conditions, especially when the prime is presented relatively briefly, reaction time to word targets that are preceded by semantically unrelated primes is not significantly different from reaction time on the neutral-prime trials. In other words, a prime that is semantically related to the target leads to a significant "benefit" in performance, relative to the neutral-prime trials, which is not associated with any "cost" when the prime and target are not related. Under other conditions, especially when the prime is presented for a relatively long period of time, reaction time to word targets on the unrelated-prime trials is significantly higher than on the neutral-prime trials. In this situation, the presence of advance information (the prime) can lead to either cost or benefit, depending on the nature of the information that is activated. Posner and Snyder (1975) presented a rationale for viewing these two patterns as automatic and effortful processes. Essentially, their idea is that when subjects are devoting attention to the meaning of the prime when it appears, reaction time will increase when the target is not semantically related to the prime, since a disruption of the subject's expectation will occur. This "cost" of using the prime is reflected in the increase in reaction time on the unrelated-prime trials. When, in contrast, the encoding of the target is automatically

influenced by the information activated by the prime, rather than by the subject's expectations, the benefit that occurs when the prime and target are related is not accompanied by any cost on the trials on which they are unrelated.

These two criteria for automaticity, the independence of performance from processing load and the presence of benefit without cost in the use of advance information, involve the interpretation of the pattern of the reaction time data that is obtained in a visual classification task. A third, and perhaps more straightforward, criterion is the lack of an instructions effect. This criterion has been typically applied in tasks that measure the accuracy of performance rather than reaction time. For example, some types of recognition memory, such as judgments regarding the relative frequency or spatial location of the items in a previously presented word list, can be performed at a level that is above chance. The accuracy of these judgments, however, has often been found to be uninfluenced by prior instructions regarding whether the recognition of frequency and location information will be subsequently required, which suggests that this type of information is encoded without attention (e.g., Hasher & Chromiak, 1977).

In an influential article, Hasher and Zacks (1979) proposed that differences between young and older adults were minimal for tasks that required automatic processing, but that these differences were substantial when effortful processing was required. This is an important proposal, because it provides a theoretical framework for age differences in various categories of tasks and indicates that reductions in available attentional capacity may be responsible for these age differences. It is thus possible that developmental invariance, or, in other words, a lack of age differences in performance, is an additional criterion for automaticity. Hasher and

Zacks provided evidence supporting their proposal in an experiment that required young and older adults to judge the frequency of occurrence of words in a previously presented list. The results indicated that for both age groups, the ability to make these judgments was above chance and was not influenced by instructions prior to list presentation that this type of judgment would be subsequently required. Similar results were reported by Attig and Hasher (1980). McCormack (1981) demonstrated that judgments regarding the serial position of items in a previously presented list were uninfluenced by instructions for both young and older adults, and that the two age groups were equivalent in terms of the accuracy of this location information.

These findings suggest that some types of item information are encoded automatically and that these encoding processes do not decline with adult age, which contrasts with the age-related deficits that are frequently reported for effortful processes such as free recall (Craik, 1977). Other recent results, however, are not consistent with the Hasher and Zacks framework. In an experiment by Kausler et al. (1982), for example, young and older adults decided the relative frequency with which instances of particular categories had appeared in a previously presented list. There was no effect of prior instructions in this task, yet the frequency judgments of the young adults were more accurate than those of the older adults, which suggests an age-related decline in an automatic encoding process. A related finding is that of Bartlett et al. (1983), who investigated subjects' ability to discriminate previously presented pictures from left-right reversals of those pictures. When the pictures had originally been presented relatively briefly, instructions regarding the nature of the judgment that would be subsequently required did not improve performance for either young or older

adults. The ability to discriminate the left-right reversals from the original pictures, however, was superior for the young adults, which, like the Kausler et al. (1982) findings, suggests an age-related decline in an automatic form of processing.

When the lack of an instructions effect is used as a criterion for automaticity, the pattern of age differences associated with frequency of occurrence and spatial orientation judgments suggests, contrary to the Hasher and Zacks theory, that an age-related decline in some automatic processes does exist. There has not as yet been extensive research on age differences in the use of advance information in choice reaction-time, and thus it is not clear whether automatic encoding in the use of advance information is constant over age. Howard et al. (1981) examined age differences in a lexical decision paradigm that are often interpreted as reflecting automatic processing by older adults. In the Howard et al. paradigm, subjects were required to decide whether or not both members of a pair of simultaneously presented letter strings were words. When both items were in fact words, reaction time was significantly faster when they were semantically related than when they were unrelated. As can be seen in the next slide, this priming effect was at least as large for a group of older adults as it was for the young adult subjects. /slide 4 about here/ In the discussion section of their article, Howard et al. stated that since the semantic priming effects in lexical decision are primarily automatic in nature, the qualitatively similar priming effects observed for the two age groups in their experiment is evidence for the preservation of automatic processing in older adults. The problem with this interpretation is that the attentional demands of semantic priming can only be inferred when there is a neutral priming condition present, and this condition is not contained in the Howard

et al. paradigm. The right-hand panel of this slide presents some data that I have recently collected in a lexical decision task that does contain a neutral priming condition. In this experiment, when the prime and target were both words, they were either related in meaning (the "associative-prime" condition), in physical structure (the "graphemic-prime" condition), or were unrelated. Subjects were only required to make a decision regarding the target items. My data resemble that of Howard et al. (1981) in that the reaction-time difference between the unrelated-prime and associative-prime conditions was at least as large for the older adults as for the young. When reaction time in the unrelated-prime and graphemic-prime conditions was compared to the neutral-prime condition, however, it was evident that substantial cost was present in this task, which means that the benefits obtained on the associative-prime trials cannot be attributed to an automatic process. I suspect that if a neutral-prime condition had been included in the Howard et al. (1981) study, reaction-time cost would have been evident on their unrelated-prime trials as well. Thus, conclusions regarding the attentional demands of a task must be made independently of the presence or absence of age differences. In reaction-time tasks that involve the presentation of advance information, it has not yet been demonstrated that there are conditions under which both young and older adults exhibit performance benefits without cost, and it is consequently too early to conclude that automatic priming effects remain constant over age.

The last of the three criteria for automatic processing described above is the independence between performance and processing load. This is a potentially important criterion, because age differences in visual-search and memory-search tasks have frequently been observed to increase as a function of processing load (Cerella et al., 1980). That is, age differences in

reaction time typically increase as the number of items to be searched is increased, which suggests the presence of an age-related deficit in effortful processing. A major obstacle in evaluating age differences in cognitive processes that are automatic by this criterion, however, is that it is very difficult to provide conditions under which subjects' reaction time is not sensitive to changes in processing load. Although Shiffrin and Schneider (1977) demonstrated that this criterion could be reached when there was a consistent mapping of stimuli to responses, apparently many thousands of trials are necessary before performance becomes independent of processing load. There have been several studies that have given both young and older adults extensive practice in consistent-mapping search tasks, such as Plude and Hoyer (1981) and Salthouse and Somberg (1982), and two types of findings have emerged from these studies. First, age differences in the attentional demands of search tasks are substantial when varied mapping is present, but these age differences are significantly reduced when the task employs consistent mapping. Second, improvements in the rate of search over practice are at least as great for older adults as for young adults. Since, however, the reaction-time functions in these experiments did not become completely independent of processing load, the changes in age differences that were obtained cannot be attributed to automatic processing. This problem can be illustrated by examining two recently published experiments. /slide 5 about here/ The left panel presents data from a consistent-mapping condition in a card-sorting task reported by Plude et al. (1982). Subjects in this experiment sorted approximately 1200 cards over two sessions of practice. The right panel presents data from a visual-search task that I recently conducted (Madden, 1983). Consistent mapping was present, and subjects performed approximately 2000 trials over four sessions. As is evident from

this graph, an interaction between age and processing load (in terms of memory-set size or display size) was not present in the statistical analysis of either experiment. That is, given the presence of consistent mapping, there are no significant age differences in the attentional demands of the search task. As was the case with the lexical decision data, however, we should not be tempted to conclude that automaticity is necessarily responsible for the fact that the young and older adults are performing in a qualitatively similar manner. There is an obvious main effect of processing load in both experiments, and thus the type of search being performed cannot be characterized as automatic.

The ideas that I have presented today can be summarized very briefly. A cognitive operation may be identified as automatic, that is, capable of being performed without attentional control, when any one of three criteria are met: an independence of performance and processing load, the presence of benefit without cost in the use of advance information, and the lack of an instructions effect. There has recently been considerable interest in the proposal that deficits in effortful processing occur during normal human aging, whereas the efficiency of automatic processes remains relatively constant over age. There is, however, relatively little evidence to support this proposal. In tasks that are not affected by instructions, such as judgments regarding frequency of occurrence, age differences are reported in some experiments but not in others. In experiments that have examined age differences in visual search and the use of advance information, the criteria for identifying performance as automatic have not been met. As a result, it is too early to add developmental invariance as an additional criterion for automaticity. Previous findings consistently indicate that there is an age-related decline in the ability to perform attention-demanding tasks. Whether

or not automatic cognitive processes are less vulnerable to this decline cannot be determined on the basis of the available data.

Footnote

[1]Presented at the 91st Annual convention of the American Psychological Association, Anaheim, CA, August 1983.

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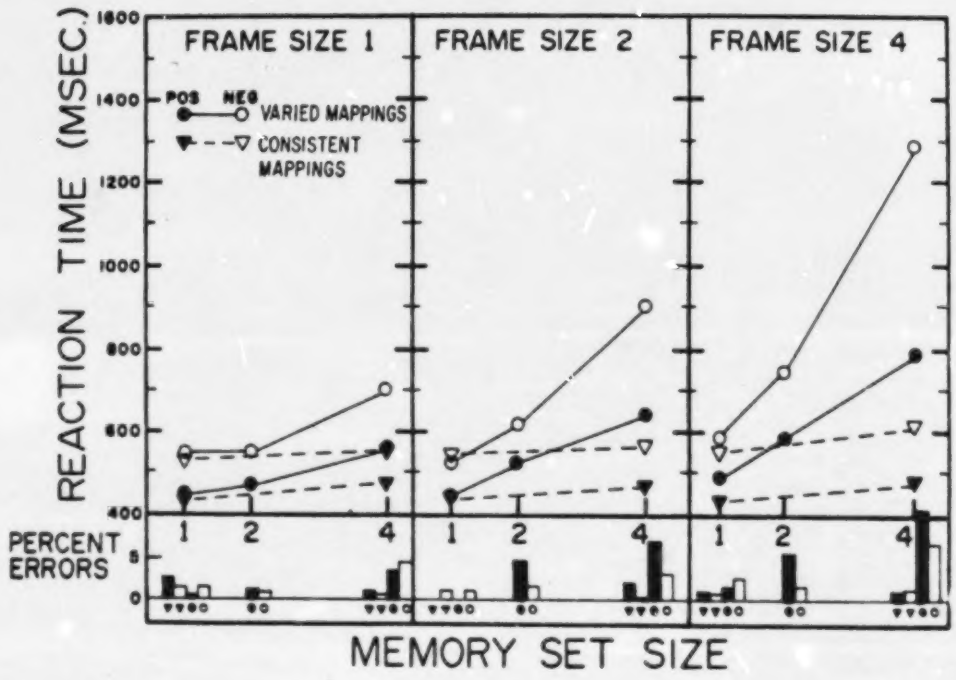
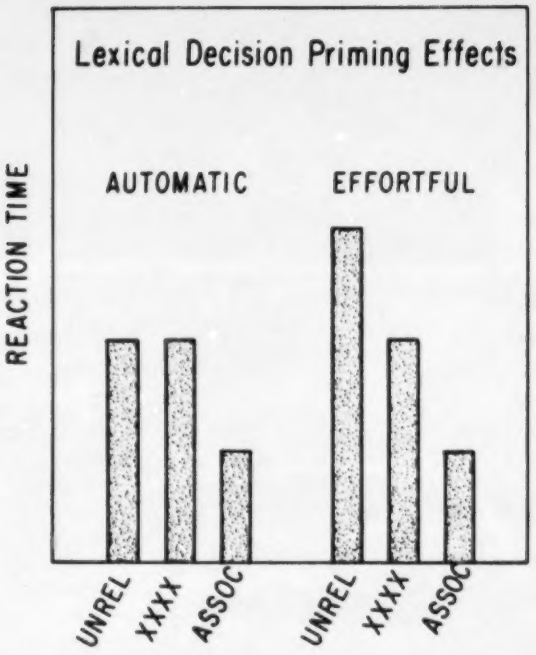


SLIDE 1

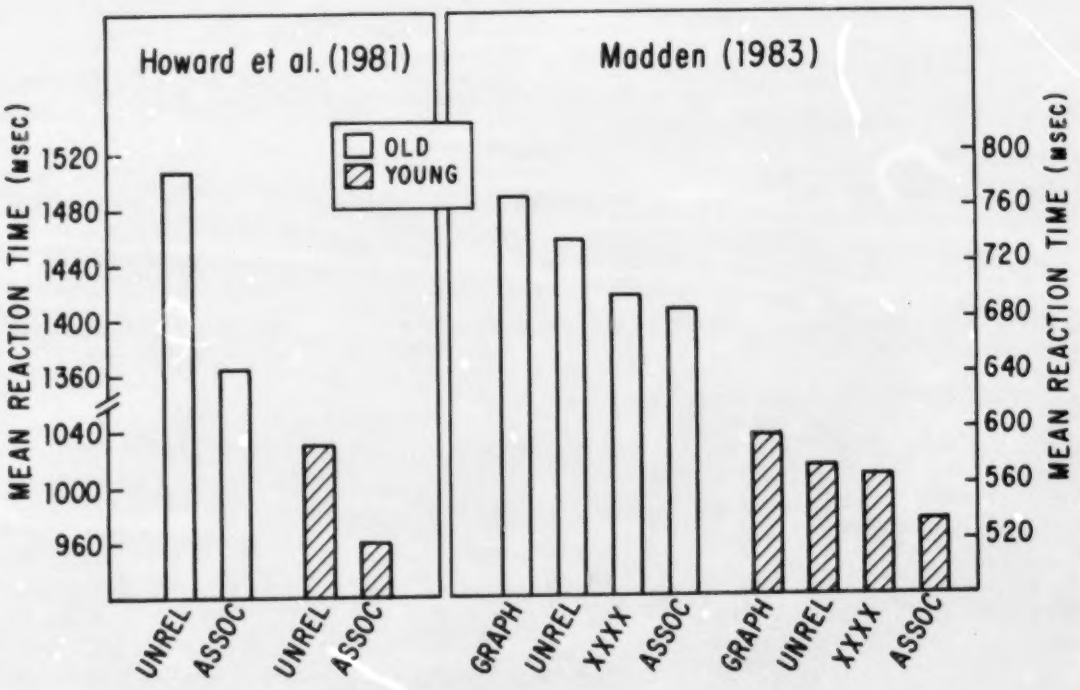
LEXICAL DECISION TASK

	PRIME	TARGET	RESPONSE
(ASSOCIATIVE)	TABLE	CHAIR	"WORD"
(UNRELATED)	KING	FENCE	"WORD"
(NEUTRAL)	XXXX	WATER	"WORD"
	HILL	SHART	"NONWORD"
	XXXX	WOON	"NONWORD"

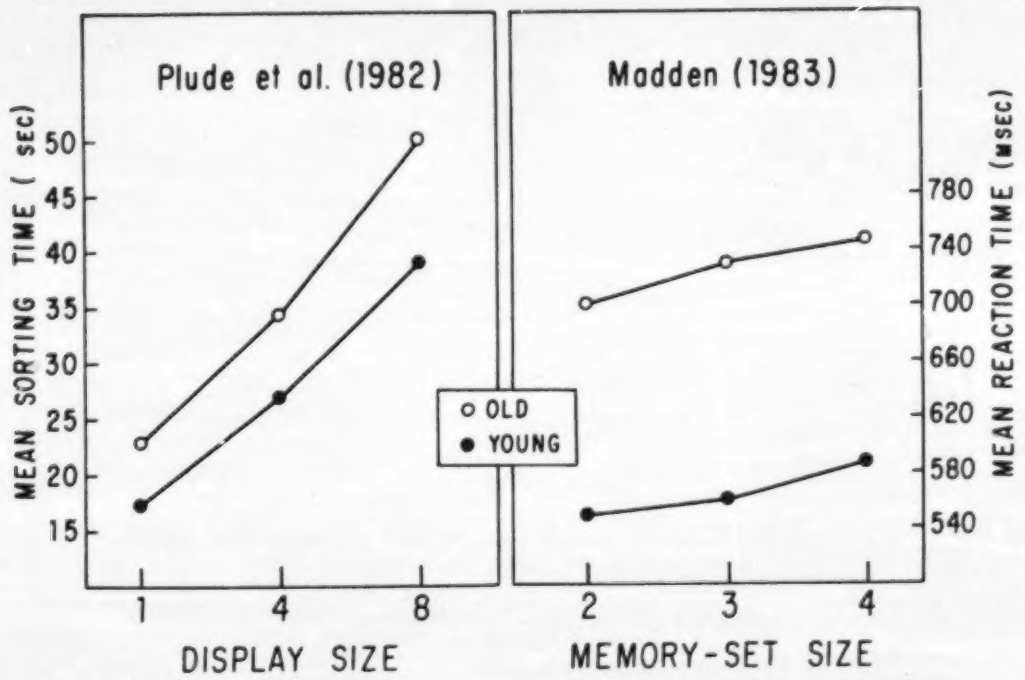
SLIDE 2



SLIDE 3



SLIDE 4


Plude et al. (1982)
Madden (1983)
MEAN SORTING TIME (SEC)
MEAN REACTION TIME (MSEC)
50
45
40
35
30
25
20
15
780
740
700
660
620
580
540
OLD
YOUNG
1
4
8
2
3
4
DISPLAY SIZE
MEMORY-SET SIZE

SLIDE 5